

IN THE UNITED STATES PATENT AND TRADEMARK

Assistant Commissioner for Patents
Washington, D.C. 20231

Attorney's Docket No.: 16864-0013

FILING TRANSMITTAL

Transmitted herewith for filing is the Patent Application of: Teng Soon Wee, Lian Boon Koh, Daming Liu, Yuan Yuan, Yong Feng Lu, Jui Kiat Goh, and Kuan Teck Chang

For: "METHOD AND APPARATUS FOR PROVIDING ABLATION-FREE LASER MARKING ON HARD DISK MEDIA"

ENCLOSURES

- ☒ 24 page application including specification, claims and abstract;
 - ☒ 14 sheets (Figs. 1 - 15) of ☐ informal/☒ formal drawings;
 - ☒ A Declaration, Power of Attorney & Petition (☒ signed/☐ unsigned);
 - ☒ A postcard for return to us as proof of receipt of the referenced documents.
- and
- ☒ An Assignment of the invention with an assignment cover sheet;
 - ☒ Verified Statement Claiming Small Entity Status (37 CFR 1.9(f) and 1.27(b));
 - ☐ IDS (form PTO-1449) and copies of references;
 - ☐ An Associate Power of Attorney;
 - ☐ A certified copy of the priority document (Under 35 USC 119);
 - ☐ A Power of Attorney by Assignee;
 - ☐ Other.

TYPE OF FILING

- ☐ This application claims the benefit of an earlier filed U.S. Patent Application (35 USC 120).
- ☒ This application claims the benefit of the priority dates of three earlier filed U.S. Provisional Patent Applications, Serial Nos. 60/089,465, 60/089,411 and 60/089,429, all filed June 16, 1998 (35 USC 119).
- ☐ This is an application filed pursuant to 37 CFR 1.53, permitting receipt of a filing date upon filing of specification, claims and drawings, if required, with applicant being given a period of one month from the date of notice to file the fee and oath or declaration.
- ☒ In the event any parts of this application are missing, please treat this as a filing under 37 CFR 1.53 as defined just above.

CERTIFICATE OF MAILING (37 CFR 1.10(a))

CERTIFICATE OF MAILING BY "EXPRESS MAIL" - Rule 10: I hereby certify that this correspondence is being deposited with the U. S. Postal Service "Express Mail Post Office to Addressee" under 37 CFR 1.10 as Express Mail No. EL300986887US addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231 on June 14, 1999, by Yolette Yturralde-Owen.

Date: June 14, 1999

Yolette Yturralde-Owen

FEE CALCULATION

The filing fee has been calculated as shown below:

				SMALL ENTITY	OR	OTHER THAN A SMALL ENTITY	
BASIC FEE Design Patent				\$155	\$	\$310	\$
BASIC FEE Utility Patent				\$380	\$380	\$760	\$
EXTRA FEES				RATE	FEE	RATE	FEE
Total claims	45	minus 20 =	25	x9 =	\$225	x18 =	\$
Independent Claims	5	minus 3 =	2	x39 =	\$78	x78 =	\$
<input type="checkbox"/> Multiple Dep. Claim				+130 =	\$	+260 =	\$
<input checked="" type="checkbox"/> Assignment				+40 =	\$40	+40 =	\$
<input type="checkbox"/> Rule 53 Surcharge				+65 =	\$	+130 =	\$
TOTAL				\$723.00			\$

FEE PAYMENT

- ☒ Attached is Check No. 5215 in the sum of \$723.00 to cover the filing fee.
- ☐ Please charge Account No. 02-3964 the sum of \$_____

FEE DEFICIENCY

- ☐ Please charge Account No. 02-3964 in the sum of \$_____
- ☒ The Commissioner is authorized to charge (or credit any overpayment) to deposit account No. 02-3964:
 - ☒ Any additional filing fees required under 37 CFR 1.16, except Rule 53 filings, which will be paid within the time permitted by PTOL 1533.
 - ☐ Assignment Recordal fees.
- ☒ The filing fee and surcharge under 37 CFR 1.16, patent application processing fees under 37 CFR 1.17 and patent issue fees under 37 CFR 1.18 are intended to be paid by our firm as they arise. As no abandonment is intended by any inadvertent nonpayment of fees, the Commissioner is hereby authorized to charge payment of such fees as from time to time come due, if not paid prior to due date to our Deposit Account No. 02-3964.
- ☐ A duplicate copy of this sheet is enclosed.

Dated: June 14, 1999

Respectfully submitted,



Chien-Wei (Chris) Chou

Reg. No: 41,672

OPPENHEIMER WOLFF & DONNELLY LLP
101 Park Center Plaza, Suite 300
San Jose, CA 95113-2218
(408) 795-3000

Attorney's File No: 16864-0013
Applicant or Patentee: Wee et al.
Serial No.: _____ Filed: _____

**VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY
STATUS (37 CFR 1.9(f) AND 1.27(c) - SMALL BUSINESS CONCERN
AND POWER OF ATTORNEY**

I am:

- ☐ the owner of the small business concern identified below;
☒ an official of the small business concern empowered to act on behalf of the concern identified below;

Name of Concern: LaserResearch, Inc.
Address of Concern: 2116A Walsh Avenue
Santa Clara, California 95050

I hereby declare that the above-identified small business concern qualifies as a small business concern as defined in 13 CFR 121.318, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full time, part-time, or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention entitled: **"METHOD AND APPARATUS FOR PROVIDING ABLATION-FREE LASER MARKING ON HARD DISK MEDIA"** by Teng Soon Wee, Lian Boon Koh, Daming Liu, Yuan Yuan, Yong Feng Lu, Jui Kiat Goh, and Kuan Teck Chang described in:

- ☒ the specification filed herein
☐ Application Serial No: _____
filed: _____
☐ Patent No.: _____
issued: _____

If the rights held by the above-identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed below* and no rights to the invention are held by any person, other than the inventor, who could not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

*NOTE: Separate Verified Statements are required from each named person, concern, or organization having rights to the invention averring to their status as small entities (37 CFR 1.27)

The undersigned hereby authorizes the firm of OPPENHEIMER WOLFF & DONNELLY LLP to correct errors in this assignment or to insert any further identification or other information necessary or desirable to make this assignment suitable for recordal in the United States Patent Office, and any Patent Office foreign to the United States.

NAME: _____
ADDRESS: _____

☐ INDIVIDUAL ☒ SMALL BUSINESS ☐ NONPROFIT ORGANIZATION

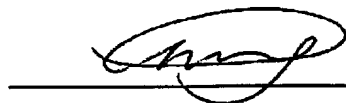
I acknowledge my duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, earliest of the Issue Fee or any Maintenance Fee due after the date on which status as a small entity is no longer appropriate (37 CFR 1.28(b)).

As an officer of the below named company, I hereby appoint W. POMS, Reg. 18,782; G.P. SMITH, Reg. 20,142; G.E. LANDE, Reg. 22,222; A.C. ROSE, Reg. 17,047; L.J. BOVASSO, Reg. 24,075; D.J. OLDENKAMP, Reg. 29,421; C. DARROW, Reg. 30,166; M.E. HARRIS, Reg. 26,690; K.A. MACLEAN, Reg. 31,118; C. ROSENBERG, Reg. 31,464; M.E. BROWN, Reg. 28,590; E.F. O'CONNOR, Reg. 25,903; R.F. CARR, Reg. 17,110; A. ROTHENBERG, Reg. 17,843; R.L. GAUSEWITZ, Reg. 16,960; M.A. KONDZELLA, Reg. 18,013; A.P. BLOCK, Reg. 35,450; S.R. HANSEN, Reg. 38,486; D.N. LARSON, Reg. 29,401; J.W. INSKEEP, Reg. 33,910; G.F. COTTERELL, Reg. 37,802; H.D. JASTRAM, Reg. 19,777; J.M. KALIS, Reg. 37,650; C.J. LERVICK, Reg. 35,244; C.A.S. HAMRICK, Reg. 22,586; R.O. GUILLOT, Reg. 28,852; J.D. VOELZKE, Reg. 37,957; G.L. FOUNTAIN, Reg. 36,374; J. BOYCE, Reg. 40,920; C. CHOU, Reg. 41,672; M. IMAM, Reg. 38,190; M. BOSWORTH, Reg. 28,186; OPPENHEIMER WOLFF & DONNELLY LLP, 101 Park Center Plaza, Suite 400, San Jose, California 95113, (408) 795-3000, as our attorneys with full power of substitution and revocation, to prosecute said application and to transact in connection therewith all business in the U.S. Patent and Trademark Office and before competent Foreign Patent Office Authorities.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful, false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful, false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this Verified Statement is directed.

Name of Person Signing: **Chang Kuan Teck, Ph.D.**
Title: **Managing Director - LaserResearch (S) Pte Ltd.**
Address of Person Signing: **41 Science Park Road, #01-02**
The Gemini, Singapore Science Park II
Singapore 117610

Signature



Date 10 June 1999

Verified Statement (Small Business Concern)

Page 2

◆SJ: 48710 v01 6/2/99

Specification

METHOD AND APPARATUS FOR PROVIDING ABLATION-FREE LASER MARKING ON HARD DISK MEDIA

5

Cross Reference to Related Applications

Reference is made to and priority claimed from provisional application serial number 60/089,411 titled "Laser Induced Deformation on Hard Disk Surface," provisional application serial number 60/089,465 titled "Laser Marking on Finished Hard
10 Disk Media," and provisional application serial number 60/089,429, titled "Laser Marking on Multi-Layered Hard Disk Media," all filed on June 16, 1998.

BACKGROUND OF THE INVENTION

15

Field of the Invention

This invention relates generally to laser marking system, and in particular, to a laser marking apparatus and method for marking the surface of a workpiece with a laser beam.

20

Description of the Prior Art

In recent years, the use of lasers in hard disk surface processing is gaining popularity. Laser pulses have already been successfully used to create landing zones with improved tribology performance for the data transducing heads. Lasers have also been identified as a viable tool for the marking or labeling of hard disk surfaces. There
25 are several occasions where disks need to be individually labeled. For example, a hard disk may contain markings indicating the number of reworks it has undergone, to assist the drive manufacturers in determining if a particular disk is suitable for further rework. Marking on an individual disk not only helps to classify the disk but also allows the drive and media manufacturers to identify the product type and trace the origin of
30 the disk should mixing occur. The media manufacturers can more easily and reliably trace faults that result in disk failure if relevant information is tagged to individual disks.

Currently, there are a few methods of marking the finished disks. Some users mark on the disk surface using a scribe. The scribe actually cuts into the delicate disk surface, abrading and damaging the top layers of the disk. Alternatively, disk marking can be carried out using some forms of ink. Ink marking may use either a jet of the liquid ink or simply a pen with a felt tip to transfer the inscription onto the disk surface. However, ink films can deteriorate with time and give rise to contamination. A disk marking method that is both non-contaminating and non-damaging is needed. The marking method also needs to be fast and efficient in order to be adopted by the manufacturing industry.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide an apparatus which uses a laser to produce visible deformations on the surface of a workpiece, especially a hard disk magnetic storage media workpiece.

It is another object of the invention to provide a method and apparatus for speedily and precisely marking hard disk magnetic storage media with a laser in a way such that surface deformation is visible, yet the protective carbon layer of the disk is intact and free of ablation.

It is yet another object of the invention to provide a method and laser apparatus for inducing surface deformation for the marking process without introducing contamination to the disk surface.

According to one aspect of the present invention, there is provided a laser beam generator, a beam conditioning module comprising a rotatable optical plate and a beamsplitter, a beam monitoring module, a beam steering module, and a materials handling unit to handle workpieces being marked. A beam from the laser generator is passed through a rotatable optical plate and a beamsplitter in the beam conditioning module, and a sample of the beam is passed to a beam monitoring module where the fluence of the beam is determined, and if desired, the rotatable optical plate can be rotated to vary the fluence of the conditioned beam leaving the beam conditioning module. The conditioned beam is passed to a beam steering module, which directs the beam to the surface of a workpiece held by the materials handling unit.

An advantage of the present invention is that a workpiece such as magnetic storage media can be marked using a laser without ablation of the protective carbon

layer, and thus no additional cleaning or processing step is required before the storage media is used.

Another advantage of the present invention is that the fluence of a laser marking beam can be adjusted without changing the power setting of the laser itself.

- 5 A further advantage of the present invention is that flashback of the laser beam from the workpiece or beamsteerer is prevented.

IN THE DRAWINGS

10 For a more complete understanding of the invention, reference is now made to the detailed description of the embodiments as illustrated in the accompanying drawings, wherein:

Fig. 1 is a block diagram of the laser marking apparatus;

Fig. 2a is a more detailed block diagram of the beam conditioning module of the laser marking apparatus;

15 Fig. 2b is a preferred embodiment of the beam conditioning module;

Fig. 3 is a more detailed diagram of the laser marking apparatus incorporating a processor;

Figs. 4 shows the front and side views of the laser marking apparatus;

Fig. 5 is a typical cross section of a finished disk;

20 Fig. 6 is a scanning electron microscopy image of the laser marks formed on the disk surface by a scanning pulsed laser beam;

Fig. 7 shows characters formed on the hard disk surface using the laser marking system;

Fig. 8 depicts laser marking on a hard disk surface without a lubricating layer;

25 Figs. 9a, 9b and 9c are data profile plots corresponding to cross-sections of an atomic force microscopy image of the ripple structure shown in Fig. 9 formed during laser marking according to the present invention;

30 Figs. 10a, 10b, and 10c are data profile plots corresponding to cross-sections of an atomic force microscopy image of the ripple structure shown in Fig. 10 formed during laser marking using a laser fluence above that of the present invention;

Fig. 11a is an auger electron spectroscopy depth profiling performed on the ripple structure of Fig. 9, and Fig. 11b is an auger electron spectroscopy depth profiling performed on a non-irradiated region on the same disk specimen;

Fig. 12 is an atomic force microscopy image of a mark made on a hard disk using a fluence above the range of the present invention;

Fig. 13 are data plots showing the results of auger electron spectroscopy performed on the surface of Fig. 12 at three locations, namely a - the center of the ripple structure, b - the rippling region and c - a non-irradiated region; and

Fig. 14 illustrates auger electron spectroscopy data profiles of scans performed at various depths of the central portion of the ripple structure of Fig. 9 showing that the surface carbon layer remains intact.

Fig. 15 is an enlarged version of Fig. 9.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A laser marking process performed on hard disks can produce two kinds of surface deformation. Commonly, the process results in severe melting and inter-diffusion of the upper metallic layers. As the protective carbon layer has also been melted, the interdiffusion between the layers can lead to possible reliability problems due to contamination of the surface layer by the underlying layers. On the other hand, with suitably low laser fluence, the marking process can bring about the necessary visible surface rippling without destroying the carbon layer. The desired fluence can be achieved by attenuating the laser beam using a rotatable optical plate and an optical device. The foregoing and other objects, features and advantages of the invention will be apparent from the following detailed description of the preferred embodiments of invention, which makes reference to the several Figs. of the drawing.

Description of the Laser-Marking System

Fig. 1 is a block diagram of the apparatus of the preferred embodiment used for marking the workpieces. A suitable laser generator 11 is employed to create an output laser beam having a unitary frequency, phase and direction. Output beam 13 from laser generator 11 is passed to a beam conditioning module 15 in which a number of operations including sizing and attenuation are performed to the beam, such that the beam is of the right quality to be delivered to the workpiece 25. If desired, a sample 16 can be taken of beam 13, said sample being passed to a beam monitoring module 18.

The beam output 19 from the beam conditioning module 15 is passed to a beam steerer 21 in which the position of the beam is manipulated to produce a beam that is

directed and focused onto the surface of a workpiece to be marked. In a preferred embodiment, the beam steerer 21 comprises a galvanometer capable of directing and focusing the output beam 23 onto the workpiece 25 which is held at a predetermined position with respect to the beam steerer 21. Such a position is within the range of focus for the output beam 23, such that the beam can be scanned across a portion of the surface of the workpiece 25 and the desired mark or pattern of marks created on the surface. Material handling unit 27 comprises an input section 28 by which each caddie or cassette 29 holding one or more workpieces enters and is placed in a suitable position for being marked by the output beam 23, and after the marking operation is carried out, the caddie or cassette 29 holding one or more marked workpieces 25 is removed to output section 30, while the next caddie or cassette of one or more unmarked workpieces are positioned at the predetermined position for marking. In an alternative embodiment, the position of output beam 23 can be fixed at a predetermined location within the range of motion of a movable materials handling unit, such as a translating X-Y stage, and the workpiece and materials handling stage can be moved with respect to the fixed position of the output beam 23, thus creating marks or a pattern of marks on the surface of workpiece 25.

Fig. 2a is a more detailed block diagram of the beam conditioning module 15. In Fig. 2a, linearly polarized beam 13 passes to beam expander and collimator 31, in which some of the properties of the beam are altered to produce an expanded beam 33. The expanded beam passes to a variable beam attenuator 34 by which the fluence of the marking beam striking the workpiece can be altered to a desired level. The variable attenuation of the output beam 33 can be achieved using a rotatable optical plate, preferably half-wave plate, and optical polarizer arrangement. A optical polarizer allows only a beam that is linearly polarized along a certain direction to pass through. By rotating the optical plate, through which the linearly polarized beam passes, about the plate's symmetry axis in a plane perpendicular to the laser beam, the direction of polarization of the beam is rotated and the component of the beam 45 that can eventually pass through the fixed polarizer is therefore varied, bringing about a variable attenuation to the beam 33.

In an alternative embodiment, variable beam attenuation can also be achieved simply by placing a rotatable polarizer in the path of the linearly polarized beam 33. As

the polarizer is rotated about its symmetry axis in a plane perpendicular to the beam 33, the component of the beam that is allowed to pass through the polarizer is also changed, leading to variable power of the output beam 45.

Output beam 45 passes to an optical isolator 47, such as a quarter wave plate, which serves to prevent reflection of the beam from the workpiece from reaching the laser generator. From optical isolator 47, the resulting beam 51 passes to an optical sampler 53 that provides a sample beam from which a responsive reading may be obtained. Main beam 19 passes from the optical sampler to the beam steering module 21 (shown in Fig. 1).

Fig. 2b shows a preferred embodiment of the beam conditioning module. Linearly polarized beam 13 from the laser passes to a beam collimator and expander 31, in which some of the properties of the beam are altered to produce an expanded beam 33. The expanded laser beam 33 passes to a rotatable half-wave retardation plate 35, located in the path of beam 33 and oriented such that the plate can be annularly rotated about its symmetry axis in a plane perpendicular to the laser beam. In passing through the rotatable optical plate 35, the direction of the plane of polarization of the beam is rotated to an extent depending upon the initial orientation of the incident beam 33 and the degree of rotation of the plate 35 around its axis, thus producing a polarization-shifted output beam 37. Output beam 37 leaving the rotatable optical plate 35 passes to a beamsplitting cube 41. The beamsplitting cube 41 splits the incoming beam into a plurality of output beams, commonly two components or beams, a *p* component beam 43 passes straight through the cube, while the *s* component beam 45 is redirected such that it exits the beamsplitter cube 41 at a 90 degree angle from the incident beam. Depending on the orientation of rotatable optical plate, the energy of the beam 37 entering the beamsplitter cube 41 can be split from about 97% *p* and 2% *s* to about 2% *p* and 97% *s*.

In this embodiment, the intensity or fluence of the output beam 23 striking the workpiece 25 can be adjusted by rotating optical plate 35 on an axis parallel to beam 33 until the desired attenuation of the output beam striking the workpiece 25 is achieved. The rotatable optical plate 35 can be rotated either manually, or by a motor responsive to a signal generated by a processor.

The beam 45 leaving beamsplitting cube 41 may be directed to a beam monitor, to a beam steering module, or, preferably, through an optical isolator before passing to

the beam monitoring and the beam steering modules. The optical isolator serves as a feedback preventer by optically isolating the laser generator 11 from unwanted reflection from further down the path of the beam. In a preferred embodiment, a quarter-wave retardation plate 47a is used in conjunction with the beamsplitting cube 41 for the purpose of optical isolation. The quarter-wave plate 47a is oriented such that plane-polarized incident beam becomes circularly polarized upon leaving the plate. Optical isolation occurs because a linearly polarized input beam from beamsplitter 41 is transformed by the optical plate into a circularly polarized output beam 51. Any portion of beam 51 reflected from the beam steerer 21 or the workpiece 25 is changed as it passes back through the quarter wave plate 47a, to a polarization orthogonal to the polarization of the beam 45 entering the optical plate. When the reflected beam passes back into the beamsplitting cube 41, the reflected beam will pass straight through the beamsplitting cube 41 and exit the beamsplitting cube from a different face than the one facing the laser generator 11. Thus, positioning quarter wave plate 47a along the path of the beam between the beam steerer 21 and the beamsplitting cube 41 will optically isolate the laser generator and prevent flashback from the workpiece 25 or the beam steerer 21 to the laser generator 11.

Beam 51 exiting the quarter wave plate 47a passes to a beamsampler 53a, which deflects sample 16 of beam 51 to a detector 57. Detector 57 produces a signal 58 responsive to the fluence of beam 51, and signal 58 is input to a meter 59 having a display responsive to the strength of beam 51. Upon leaving beamsampler 53a, the main body of the conditioned beam 19 passes to the beam steering module 21 as shown in Fig. 1.

As shown in Fig. 3, a further preferred embodiment of the present invention is the use of a processor 101 to control and synchronize various components of the apparatus and facilitate the method for producing marked workpieces using the present apparatus. The processor contains memory, a CPU, a display and an input device such as a keyboard through which the user can interact with the processor, and is capable of receiving one or more signals responsive to the condition of the status of said laser generator, the pattern of marks to be placed on said workpiece, the direction of said selected beam leaving said beam steerer, and the position of the workpiece relative to the beam steerer, as well as being capable of generating one or more signals affecting at least one of the status of said laser generator, the desired pattern of

marks to be made on the surface of said workpiece, the direction of the beam leaving the beam steerer, and the position of the workpiece to be marked. The processor 101 communicates with laser 11 through signal 103 by which the processor sets various parameters of the laser, such as frequency of laser pulses and laser power. Processor 101 receives signal 105 responsive to the status of the laser, e.g., Q-switch frequency and power level. The processor can send signal 107 to vary the setting of the beam expander 31, and thus vary the size of the beam. Processor 101 can also send a signal 111 to a motor 112 capable of rotating rotatable optical plate 35 along its axis and thus alter the intensity or fluence of the output beam 23 reaching the workpiece 25.

Shutter 133 can send a bi-directional signal 113 to processor 101 to indicate whether the shutter is in an open or closed status, and processor 101 can in response signal the shutter 133 to maintain or change the status. The processor can receive signal 114 from meter 59 responsive to the power of the sampled beam, and can subsequently issue a command to rotate rotatable optical plate 35 along its axis if the desired fluence or intensity of the output beam 23 reaching the workpiece is not within the desired range or at pre-established setpoint.

The processor 101 is also capable of receiving input from the user on the pattern of markings to be made on the surface of the workpiece 25, and converting the pattern to a digital representation, which the processor can then transmits to the beam steerer 21 by means of signal 115. Using signal 115, the processor can control the position of output beam 23 striking the surface of the workpiece 25, so as to create a predetermined marking pattern on the surface of the workpiece 25.

Signal 117 is generated by beam steerer 21 and sent to the processor 101 responsive to the position of the output beam 23 on the workpiece 25. Signal 131 is generated by the materials handling unit 27 responsive to the position of the workpiece 25 and sent to the processor 101, while signal 121 is generated by the processor 101 and sent to the materials handling mechanism to have it change the position of the workpiece 25. If the laser 11 is operated using a Q-switch, the operation of the Q-switch may be controlled by signal 103 from processor 101 or directly controlled by a signal 123 from the beam steerer 21, bypassing any delay by the processor 101.

If the laser 11 comes equipped with an integral controller, many of these functions can be placed in the correct settings, independent of the external processor

101, by using the integral controller. Other input signals to the processor 101, such as a workpiece proximity detector, will be apparent to those skilled in the art.

The preferred method of carrying out the present invention can be described with reference to Fig. 3. A Q-switched, diode-pumped laser generator 11 operating in the Gaussian mode and with a wavelength of 1064 nanometers is employed. Use of diode laser is preferred because a diode-pumped laser is more efficient, longer lasting, more durable and has a higher-quality laser output than the use of a flashlamp pumping scheme. Use of a Q-switch scheme is advantageous because it causes pulse repetition emission with a relatively high peak pulse energy. Other types of laser generators may be used, so long as they emit a beam at a wavelength that is capable of generating sufficient heat to melt a portion of the desired layer of the workpiece. To ensure pulse-to-pulse uniformity in the marking process, the laser is made to operate in the pre-lasing mode; that is, the Q-switch is set such that between pulses, the laser generator 11 is running slightly over threshold in continuous-wave mode with a low output power. When the Q-switch is turned off, a laser pulse is built up from the already present reproducible continuous-wave pre-lasing signal instead of from a spontaneous emission in the lasing cavity when no prelasing is present. The prelasing operation ensures that the pulse-to-pulse noise is less than about 5% and preferably less than 2%.

In a preferred embodiment, the beam 13 emerging from laser generator 11 is linearly polarized, and beam 13 passes through a beam collimator and expander 31. Beam expander 31 alters the size of the beam to achieve the desired beam spot size after the beam is focused on the surface of the workpiece. This size of the spot on the surface of the workpiece determines the actual beam intensity used to mark the workpiece surface, with small spot sizes resulting in markings of high resolution. The expanded beam 33 leaving the beam expander 31 passes through a rotatable optical plate 35, which has the effect of rotating the polarizing plane of the beam, and then through shutter 133, which is employed as a safety device to block the laser beam when the laser marking apparatus is not in use. The laser generator 11, beam expander 31 and shutter 133 receive signals from and send signals to processor 101 responsive to desired or actual settings or levels of operation.

The beam 37 enters the polarizing beamsplitting cube 41 where the beam is separated into its *p*- and *s*- polarization components, which component beams emerge

from different faces of the cube. Although either the *p*- or *s*- component beams could be used to mark the workpiece, in a preferred embodiment, the *s*- component is used. While the *p*- component passes linearly through the cube 41, the *s*- component is reflected at an angle, and exits a different face of the cube where it passes to optical plate 47. The beam 51 exiting optical plate 47 is monitored by a beam sampler 53 in which a sample 16 of the incident beam is removed and directed to detector 57 which generates a responsive signal 58 that is used to create a display on meter 59 or as an input to processor 101. The intensity of the beam 23 striking the workpiece can be varied in response to signal 58 by rotating rotatable optical plate 35 to attenuate the beam 37 to a greater or lesser degree instead of having to alter the controls of the laser power supply with the resulting undesirable beam power instability.

Laser beam 19 from the sampler 53 passes to beam steerer 21, which in a preferred embodiment is a galvanometer. The beam steering module, acting pursuant to a signal 115 from processor 101, positions and focuses beam 23 on the surface of the workpiece 25, and on receiving appropriate instructions from the processor 101, the beam steering module scans the beam across the surface of the workpiece 25 while signals sent to laser 11 initiate laser pulses at appropriate times in the marking cycle to inscribe the desired marks or pattern of marks on the surface of the workpiece 25. As the laser beam is preferably in the form of pulses, scanning the beam 23 across the surface of the workpiece 25 according to a predetermined pattern input into the processor 101 produces laser-induced dot-like marks along the path of the scan. By scanning the laser beam along closely-spaced multiple lines and controlling the points at which the pulses strike the workpiece, alphanumeric patterns can be formed on the workpiece for identification purposes. The spacing between two adjacent marks is determined by the laser Q-switch frequency and the beam scanning speed, both of which can be controlled by the processor. The spacing of the marks determines the visual contrast of the marked patterns on the surface of the workpiece.

In the materials handling unit 27, a workpiece is moved into position for being marked, preferably held in a fixed position while processor 101 signals for beam steerer 21 to vary the position of the beam striking the workpiece, so as to form the desired mark (surface deformation) or pattern of marks. Although workpieces can be handled individually, the materials handling unit typically comprises a magazine or cassette designed to hold multiple workpieces, which workpieces are individually marked. When

all of the workpieces in the cassette or magazine have been marked, the magazine or cassette of marked workpieces is replaced with one containing unmarked workpieces.

Fig. 4 depicts front and side views of a typical arrangement of the apparatus of the present invention. Cart 301 houses a diode pump 303 for laser 11. The beam from laser 11 passes through beam conditioning module 15 (not to scale) and a select beam passes to beam steering module 21, where it emerges as beam 23 directed to the workpiece 25. Workpiece 25 is positioned for marking by materials handling unit 27, which is controlled by processor 101, in this case, a laptop computer. The materials handling unit is capable of handling caddies or cassettes 29 of workpieces as part of a continuous operation.

Another aspect of the invention relates to marking a workpiece, and typically a multi-layered workpiece such as one which comprises a substrate, a first layer placed over said substrate, said first layer having a first melting point, one or more additional layers placed over said first layer, said additional layers having melting points higher than said first melting point, and a protective layer placed over said additional layer. The invention is especially suited to marking multi-layered workpieces such as magnetic storage media such as a computer hard disk, in which the first layer comprises nickel-phosphorous, the additional layers comprise a chromium layer and a magnetic layer, and the protective layer comprises carbon. The invention is particularly advantageous when applied to marking a finished computer hard disk, which typically comprises multiple layers on an aluminum substrate, as shown in Fig. 5.

As shown in Fig. 5, the topmost layer 201 of such a disk is commonly an organic lubricant, a few nanometers thick. Below the lubricating layer 201 is a carbon layer 203 about 10 to 30 nanometers thick that serves as a protective coating for the magnetic layer 205 underneath. The magnetic layer 205 comprises mainly cobalt, with some chromium and small traces of platinum and/or tantalum, and is commonly 50 to 70 nanometers thick. Below the magnetic layer 205 is a chromium layer 207 which is typically 100 to 200 nanometers thick, followed by a nickel-phosphorus layer 209 which typically is about 10 micrometers thick, on a substrate 211 such as aluminum or other durable material.

A disk marked pursuant to the present invention will have visible surface deformations created by laser-induced rippling in the nickel phosphorous layer 209, while the integrity of the protective carbon layer 203 at the point of said deformation is

substantially maintained. The laser will have a wavelength from 400 to 10,000 or more nanometers, a duration of 30 to 120 nanoseconds, and a pulse frequency of 1 to 100 kilohertz. In a preferred embodiment, the disk will have been marked by a laser having a wavelength of 1064 nanometers, a pulse length of about 50 nanoseconds, and the
 5 fluence of the beam at the surface of the workpiece is within the range of 0.5 to 1.5 joules/square centimeter, preferably 0.8 joule/sq. cm., in a laser spot size having a diameter from 10 to 30 micrometers, and preferably 15 micrometers.

The laser can be either continuous wave, or pulsed. Preferably, the laser beam is made up of pulses, such that scanning the laser beam across the workpiece surface
 10 results in the formation of laser-induced dot-like marks along the line of scan, as shown in Fig. 6. A laser having a spot size of about 30 micrometers was used to form the marks shown in Fig. 6, and within each mark structure there are ripples which are more prominent than others.

By scanning the laser along closely-spaced multiple lines, patterns of letters and
 15 numbers can be formed for labeling or marking purposes, as shown in Fig. 7. The spacing between two adjacent marks is determined by the laser Q-switch frequency and the beam scanning speed. This spacing will subsequently affect the visual contrast of the marked patterns on the workpiece surface. However, the scope of the present invention includes the use of a continuous laser, which will produce a
 20 continuous marking line on the surface of the workpiece.

During a typical laser marking process, the topmost lubricating layer (201 on Fig. 5) at the spots where the intense laser pulses strike the workpiece surface would have been evaporated off. However, the visual contrast obtained by use of the present invention is not due to the loss of the lubricating layer. In Fig. 8, the desired visual
 25 contrast has been obtained on a workpiece where the lubricating layer is not originally present.

Figs. 9 and 10 show a typical surface morphology, and related data profiles of cross-sections of atomic force microscopy images of the ripple structure formed during laser marking, Fig. 9 being marking formed in accord with the present invention, and
 30 Fig. 10 showing the results from use of a higher intensity beam which melts the protective coating. The laser fluence used was about 1 J/sq. cm for Fig. 9 and 2.7 J/sq. cm for Fig. 10. In both cases, a circular ripple structure was obtained. Such a structure is linked to the axial-symmetrical Gaussian-shaped intensity distribution of the

laser beam. The ripple periodicity is around 1 to 2 micrometer. No micro-cracks were seen in the vicinity of the structure, and the magnitude of surface deformation around the rim of the ripple structure subsides gradually towards the non-irradiated region. Due to the smaller rippling structure formed, compared to that formed using a spot size of about 30 micrometer (see e.g., Fig. 6), the outwardly radiating ripples are more uniform than when a larger spot size is used.

Fig. 9b is a data profile of a cross section taken along line **b** traversing the central portion of the ripple structure on Fig. 9. The lack of significant peaks or valleys in the profile indicates that the central region of the ripple structure is at about the same level as the surface of the workpiece. Figs. 9a and 9c are data profiles of cross sections taken along lines **a** and **c** traversing the ripple structure depicted in Fig. 9 on either side of the central portion. The similar heights and depths of the peaks and valleys of the data profile indicates that the rippling occurs quite symmetrically about the surface level of the workpiece, demonstrating that the volume of the workpiece material was more or less conserved before and after laser irradiation.

Since the melting points of carbon - 3800 K, cobalt - 1768 K, platinum - 2041 K, tantalum - 3290 K and chromium - 2130 K are all higher than that of the nickel-phosphorus - 1200 K, the fluence of the laser was such that the laser only melted part of the nickel phosphorus layer while the upper two metallic layers and the carbon layer still remained reasonably solid. The interfacial stress exerted by the upper two metallic layers and the carbon layer acts as a restoring force controlling the movement of melted nickel phosphorus. Within a confined space, the volumetric change during rapid localized melting and subsequent re-solidification therefore brings about the rippling observed.

Fig. 10b is a data profile of a cross section taken along line **b** traversing the central portion of the ripple structure on Fig. 10. Fig. 10b shows a laser-induced structure with a different surface morphology from Fig. 9b. The structure of Fig. 10b has a raised circular central region surrounded by an annular rippling region. The data profiles of cross sections of the ripples are depicted in Figs. 10a and 10c, representing cross sections taken along lines **a** and **c** traversing either side of the central portion of the ripple structure depicted in Fig. 10.

Fig. 11a is an auger electron spectroscopy depth profiling performed on the center of the ripple structure of Fig. 9, and Fig. 11b is an auger electron spectroscopy

depth profiling performed on a non-irradiated region on the same disk specimen. On the left axis of Fig. 11a, it can be seen that the concentration of carbon nearest the surface (at the least depth) of a ripple approximates 100%, similar as what is shown in Fig. 11b for the concentration of carbon nearest the surface of a non-irradiated region of the same disk. Thus, auger electron spectroscopy depth profiling performed on the center of the structure in Fig. 9, when compared to profiling performed on a non-irradiated region on the same specimen, indicates that the carbon layer has remained very much intact, and that the interfaces between the metallic layers are well preserved.

Referring now to Fig. 12, there is depicted an atomic force microscopy image of a mark made on a hard disk using a laser fluence above that of the present invention, and three locations are marked on the surface, namely, **a** the center of the circular region, **b** the rippling region and **c** a non-irradiated region. Auger electron spectroscopy was performed on the surface at these locations and the results are shown in Fig. 13. The plot of the results indicates that at locations **b** and **c**, the surface layer contains only carbon, whereas at the surface at point **a** contains a mixture of carbon, chromium, and cobalt. Thus, at the circular central region of a mark formed using a laser fluence higher than that taught in the art, one or more of the upper metallic layers have melted together with the nickel-phosphorus layer, resulting in severe mass diffusion and material mixing. Due to the fact that the different layers have either been melted together or inter-diffused into one another, no surface rippling was obtained. The interfaces between different layers are almost no longer distinguishable. As the carbon layer, serving as a protective layer for the disk, has already been mixed with other materials, such a laser-induced deformation can lead to potential disk failures.

On the other hand, auger electron spectroscopy data profiles of scans taken at various depths of the central portion of the ripple structure of Fig. 9 are shown in Fig. 14. The auger electron spectroscopy was carried out repeatedly after every 5 minutes of sputter etching, and the spectrum at the respective depth was plotted. The first spectrum at the bottom corresponds to the surface level, while the topmost spectrum corresponds to a depth obtained after 95 minutes of sputter etching. The peak for carbon at the lowermost profiles remains well differentiated from the peaks for cobalt. Similarly, the peaks for cobalt remain well differentiated from the peak for chromium in

the profiles at the corresponding depth. Subsequent profiles show that there is some interdiffusion of the chromium and nickel-phosphorous interfaces. Thus, the laser-induced deformation carried out according to the teachings of the present invention have been limited to formation of surface rippling required in the marking process, while

5 leaving the protective upper layer substantially intact and functional.

While the invention has been particularly shown and described with reference to certain preferred embodiments, it will be understood by those skilled in the art that various alterations and modifications in form and detail may be made therein. Accordingly, it is intended that the following claims cover all such alterations and

10 modifications as they fall within the true spirit and scope of the invention.

What is claimed is:

CLAIMS

1 1. A laser apparatus for creating visible surface deformations on the surface of a
2 workpiece such as a multi-layered workpiece including an upper carbon layer, at least
3 one intermediate metallic layer, and a lower substrate, comprising:

4 (a) a laser generator for generating an output laser beam;

5 (b) a beam conditioner responsive to said output laser beam and operative to
6 generate a conditioned laser beam, said beam conditioner including (i) a beam
7 expander responsive to said output laser beam and operative to generate an expanded
8 laser beam and (ii) a variable beam attenuator responsive to said expanded laser
9 beam and operative to generate a conditioned marking beam;

10 (c) a beam steerer for directing said marking beam to a surface of a workpiece;

11 and

12 (d) a materials handler for positioning said workpiece in the path of said marking
13 beam.

1 2 A laser apparatus as recited in Claim 1 wherein said variable beam attenuator
2 includes a first optical plate responsive to said expanded laser beam and operative to
3 generate a conditioned laser beam; and a beamsplitter responsive to said conditioned
4 laser beam and operative to split said conditioned laser beam into a plurality of beams
5 including said marking beam.

1 3. A laser apparatus as recited in Claim 2 wherein said first optical plate is
2 rotatable along an axis parallel to that of said laser beam and operative to vary the
3 fluence of said marking beam striking said workpiece.

1 4. A laser apparatus as recited in Claim 2 wherein said first optical plate is a half-
2 wave plate.

1 5. A laser apparatus as recited in Claim 1 wherein further comprising a beam
2 sampler and a detector, said beam sampler being positioned in the path of said
3 marking beam and capable of passing a sample of said marking beam to said detector,

- 4 said detector being capable of receiving said sample and generating a signal
5 responsive to the fluence of said marking beam.

1 6. A laser apparatus as recited in Claim 1 wherein said variable beam attenuator
2 includes a beamsplitter, and wherein said apparatus further comprises an optical
3 isolator for optically isolating the laser generator from any reflection of said marking
4 beam to said laser generator, said optical isolator including a second optical plate
5 positioned in the path of said marking beam, whereby the polarization plane of any
6 reflection of the marking beam is rotated such that the reflection exits the beamsplitter
7 in a direction away from said laser beam generator.

1 7. A laser apparatus as recited in Claim 6 wherein said second optical plate is a
2 quarter-wave plate.

1 8. A laser apparatus as recited in Claim 1 wherein said laser generator includes a
2 Q-switched diode-pumped laser.

1 9. A laser apparatus as recited in Claim 1 further comprising a processor capable
2 of receiving one or more signals responsive to one or more of variables from the group
3 consisting of the status of said laser generator, the pattern of marks to be placed on
4 said workpiece, the direction of said selected beam leaving said beam steerer, and the
5 position of the workpiece relative to the beam steerer, said processor being capable of
6 generating one or more signals affecting the status of said laser generator, the desired
7 pattern of marks to be made on the surface of said workpiece, the direction of the
8 beam leaving the beam steerer, or the position of the workpiece to be marked.

1 10. A laser apparatus as recited in Claim 1 wherein said laser generator is operated
2 in a pre-lasing mode.

1 11. A laser apparatus as recited in Claim 1 wherein said selected beam is scanned
2 across a portion of the surface of said workpiece to form deformations therein in a
3 predetermined pattern.

1 12. A laser apparatus as recited in Claim 11 wherein the resolution of said pattern is
2 determined by varying the size of the beam from said beam conditioner.

1 13. A laser apparatus as recited in Claim 11 wherein said laser beam is in pulses,
2 and the contrast of said pattern is varied by changing one or more of the group
3 consisting of pulse energy, pulse frequency and laser beam scanning speed.

1 14. A method for creating a surface deformation on the surface of a workpiece such
2 as a multi-layered workpiece including a substrate, a first layer placed over said
3 substrate and having a first melting point, one or more additional layers placed over
4 said first layer and having melting points higher than said first melting point, and a
5 protective layer placed over said additional layers, said method comprising the steps
6 of:

- 7 (a) generating a laser beam;
- 8 (b) expanding said laser beam to a predetermined diameter;
- 9 (c) attenuating the expanded beam to a level suitable for creating said surface
10 deformation.
- 11 (d) passing the attenuated beam to a beam steerer to produce an output
12 marking beam;
- 13 (e) positioning said workpiece in the path of said marking beam;
- 14 (f) creating one or more deformations on a surface of said workpiece by
15 scanning said marking beam over said surface.

1 15. A method as recited in Claim 14 wherein said expanded beam is attenuated by
2 passing said expanded beam through a first optical plate and passing the output from
3 said first optical plate through an optical device responsive to said first optical plate,
4 thus producing said attenuated beam.

1 16. A method as recited in Claim 15 wherein said first optical plate is rotatable along
2 an axis parallel to that of said laser beam and operative to attenuate said marking
3 beam.

1 17. A method as recited in Claim 15 wherein said optical device is a beamsplitter
2 operative to produce a plurality of beams, including said attenuated beam.

1 18. A method as recited in Claim 15 further comprising optically isolating said laser
2 generator from said workpiece by positioning a second optical plate in the path of said
3 attenuated beam.

1 19. A method as recited in Claim 18 wherein said first optical plate is a half-wave plate
2 and said second optical plate is a quarter-wave plate.

1 20. A method as recited in Claim 14 further comprising taking a sample of said
2 attenuated beam, determining the fluence of said attenuated beam from said sample,
3 and generating a signal responsive to said fluence.

1 21. A method as recited in Claim 14 further comprising using a processor to obtain
2 signals responsive to the status of one or more of the group consisting of laser beam
3 on/off status, position of the beam steerer, and position of the workpiece, and to
4 generate one or more signals to control one or more of the group consisting of the
5 frequency, fluence, spot size, on/off status and scanning speed of said marking beam,
6 and movement of said marking beam relative to said workpiece.

1 22. A method as recited in Claim 21 further comprising forming said deformations in
2 a predetermined pattern on a portion of said surface of said workpiece by inputting a
3 predetermined pattern into said processor and using the processor to control scanning
4 said marking beam over said portion.

1 23. A method as recited in Claim 22 further comprising forming said deformation by
2 melting said first layer while substantially maintaining the integrity of said protective
3 layer.

1 24. A method as recited in Claim 14 further comprising forming a pattern of
2 deformations on a portion of said surface by controlling one or more of the group
3 consisting of the frequency, fluence, spot size, and on/off of said marking beam, and

4 the scanning speed and relative position of said marking beam with respect to the
5 surface of said workpiece.

1 25. A method as recited in Claim 14 wherein said laser beam is generated by a
2 diode-pumped laser.

1 26. A method as recited in Claim 25 wherein said laser is operated in a pre-lasing
2 mode.

1 27. A method as recited in Claim 25 wherein said laser beam is pulsed, the beam
2 pulses being formed by a Q-switch operating said laser.

1 28. A workpiece having a surface marked by selectively located deformations and
2 including a substrate, a first layer adjacent to said substrate and having a first melting
3 point, one or more additional layers, at least one of which is adjacent to said first layer,
4 said additional layers having melting points substantially above said first melting point,
5 and an outer protective layer adjacent to the outermost of said additional layers, the
6 surface of said workpiece having laser-induced visible surface deformations and a
7 substantially intact protective layer over said deformations, said deformations being
8 formed by a method which comprises the steps of

9 ((a) generating a laser beam;

10 (b) expanding said laser beam to a predetermined diameter;

11 (c) attenuating the expanded beam to a level suitable for creating said surface
12 deformation.

13 (d) passing the attenuated beam to a beam steerer to produce an output
14 marking beam;

15 (e) positioning said workpiece in the path of said marking beam;

16 (f) creating one or more deformations on a surface of said workpiece by scanning said
17 marking beam over said surface.

1 29. A workpiece as recited in Claim 28 wherein said expanded beam is attenuated
2 by passing said expanded beam through a first optical plate and passing the output

3 from said first optical plate through an optical device responsive to said first optical
4 plate, thus producing said attenuated beam.

1 30. A workpiece as recited in Claim 29 wherein said first optical plate is rotatable
2 along an axis parallel to that of said laser beam and operative to attenuatesaid marking
3 beam.

1 31. A workpiece as recited in Claim 29 wherein said optical device is a beamsplitter
2 operative to produce a plurality of beams, including said attenuated beam.

1 32 A workpiece as recited in Claim 28 wherein said laser generator is optically
2 isolated from said workpiece by positioning a second optical plate in the path of said
3 attenuated beam.

1 33. A workpiece as recited in Claim 32 wherein said first optical plate is a half-wave
2 plate and said second optical plate is a quarter-wave plate.

1 34. A workpiece as recited in Claim 28 further comprising maintaining said
2 workpiece at a predetermined location with respect to said beam steerer during said
3 scanning.

1 35. A workpiece as recited in Claim 28 wherein said marking beam is pulsed and
2 has a fluence of about 0.8 Joule/square centimeter, a wavelength of 1064 nanometer,
3 and a pulse duration of about 50 nanoseconds.

1 36. A workpiece as recited in Claim 28 wherein said laser beam is generated by a
2 diode - pumped laser.

1 37. A workpiece as recited in Claim 28 wherein said workpiece is a magnetic media
2 hard disk, said first layer including nickel-phosphorous, said additional layers including
3 a chromium layer and a magnetic layer, and said protective layer including carbon, said
4 workpiece also containing a surface lubricant adjacent to said protective layer.

1 38. A workpiece as recited in Claim 37 wherein said disk is a clean finished disk.

1 39. A workpiece as recited in Claim 28 wherein said deformation is produced by
2 laser-induced melting and subsequent resolidification of said first layer while
3 maintaining the integrity of said carbon layer.

1 40. In a method for making a workpiece having visible surface marking, said
2 workpiece having multiple layers including a substrate, a first layer with a first melting
3 point adjacent to said substrate, one or more additional layers at least one of which is
4 adjacent to said first layer, said additional layers having melting points substantially
5 above said first melting point, and a protective layer adjacent to the outermost of said
6 additional layers, the improvement comprising: creating said surface marking by
7 melting said first layer while leaving said protective layer substantially intact by using a
8 laser beam having a wavelength within the range of about 400 to about 10,000
9 nanometers, a pulse duration within the range of about 30 to about 120 nanoseconds,
10 a pulse frequency from about 1 to about 100 kilohertz, a laser fluence from about 0.5 to
11 about 1.5 Joules/square centimeter, and a laser spot size diameter from about 10 to
12 about 30 micrometers.

1 41. A method for making a workpiece as recited in Claim 40 wherein said laser
2 beam has a fluence of about 0.8 Joule/square centimeter, a wavelength of 1064
3 nanometers, and a pulse duration of about 50 nanoseconds.

1 42. A workpiece having visible surface marking and multiple layers including a
2 substrate, a first layer adjacent to said substrate having a first melting point, one or
3 more additional layers at least one of which is adjacent to said first layer and with
4 melting points substantially above said first melting point, and a protective layer
5 adjacent to the outermost of said additional layers, said markings being formed by
6 melting said first layer while leaving said protective layer substantially intact by using a
7 laser beam having a wavelength within the range of about 400 to about 10,000
8 nanometers, a pulse duration within the range of about 30 to about 120 nanoseconds,
9 a pulse frequency from about 1 to about 100 kilohertz, a laser fluence from about 0.5 to

10 about 1.5 Joules/square centimeter, and a laser spot size diameter from about 10 to
11 about 30 micrometers.

1 43. The workpiece as recited in Claim 42 wherein said laser beam has a fluence of
2 about 0.8 Joule/square centimeter, a wavelength of 1064 nanometers, and a pulse
3 duration of about 50 nanoseconds.

1 44. The workpiece as recited in Claim 42 wherein said markings have the general
2 ripple structure shown in Fig. 9 herein, and representative data profile plots as shown
3 in Figures 9a, 9b, and 9c herein.

1 45. The workpiece as recited in Claim 42 wherein said markings have the general
2 ripple structure shown in Fig. 6 herein.

11/11/2019 10:00:00 AM

ABSTRACT

A method and apparatus for creating ablation-free visible markings on a multi-layer hard disk magnetic storage media by laser-induced deformation while maintaining the integrity of the protective carbon layer, and without destroying the multi-layered structure of the media. The apparatus includes a laser generator, a rotatable optical plate and a beamsplitter by which the fluence of the beam can be controlled without altering the power setting to the laser generator, a beam sampler for determining the fluence of the beam, and an optical plate which acts with the beamsplitter to eliminate unwanted reflection of the laser beam. The laser beam is steered by a beamsteerer to a hard disk held in a material handling unit. This technique is highly suitable for marking or labeling finished hard disks for the purposes of identification and traceability, without creating any short-term or long-term contamination problems. The corresponding storage media so marked are also claimed.

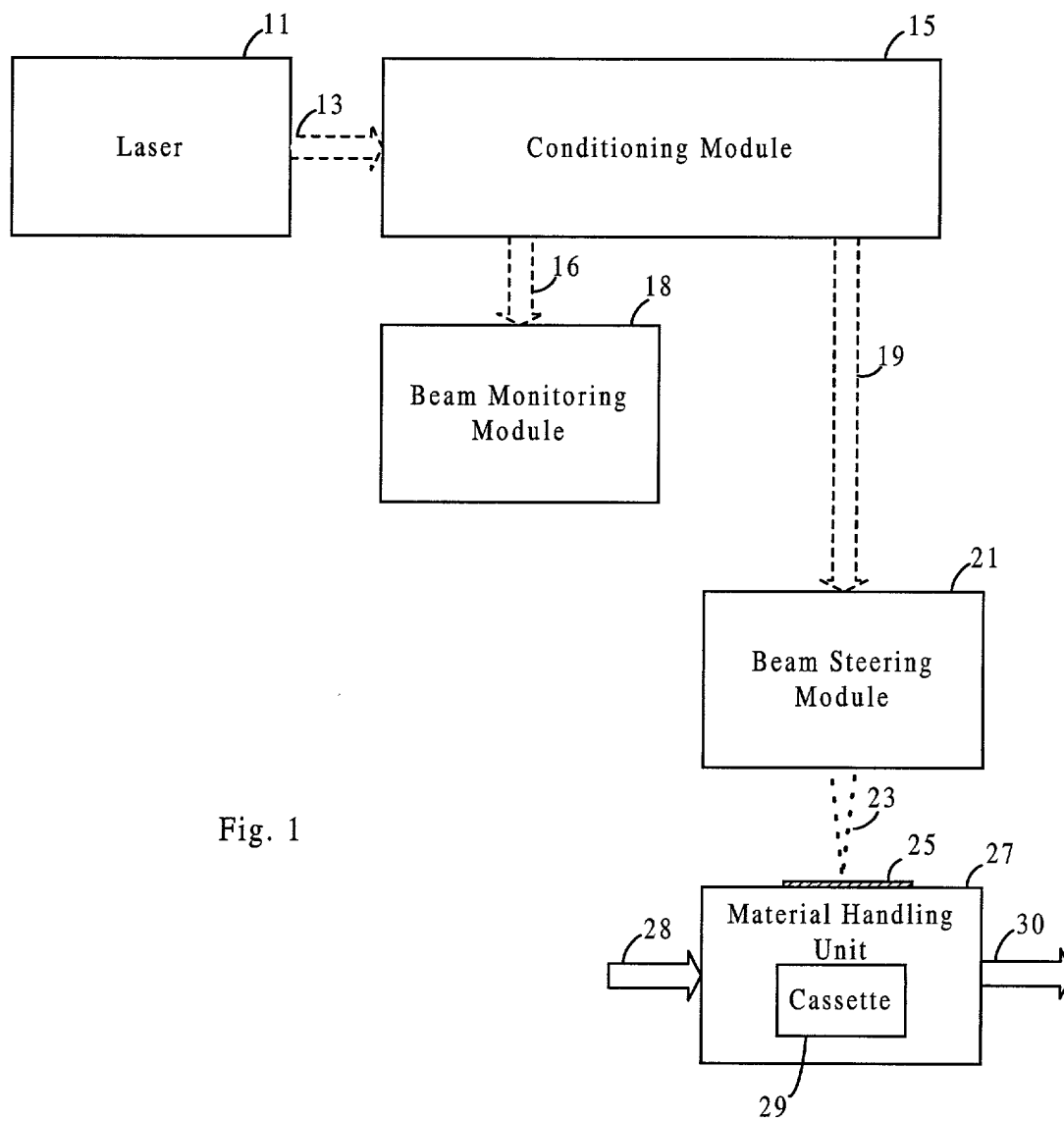


Fig. 1

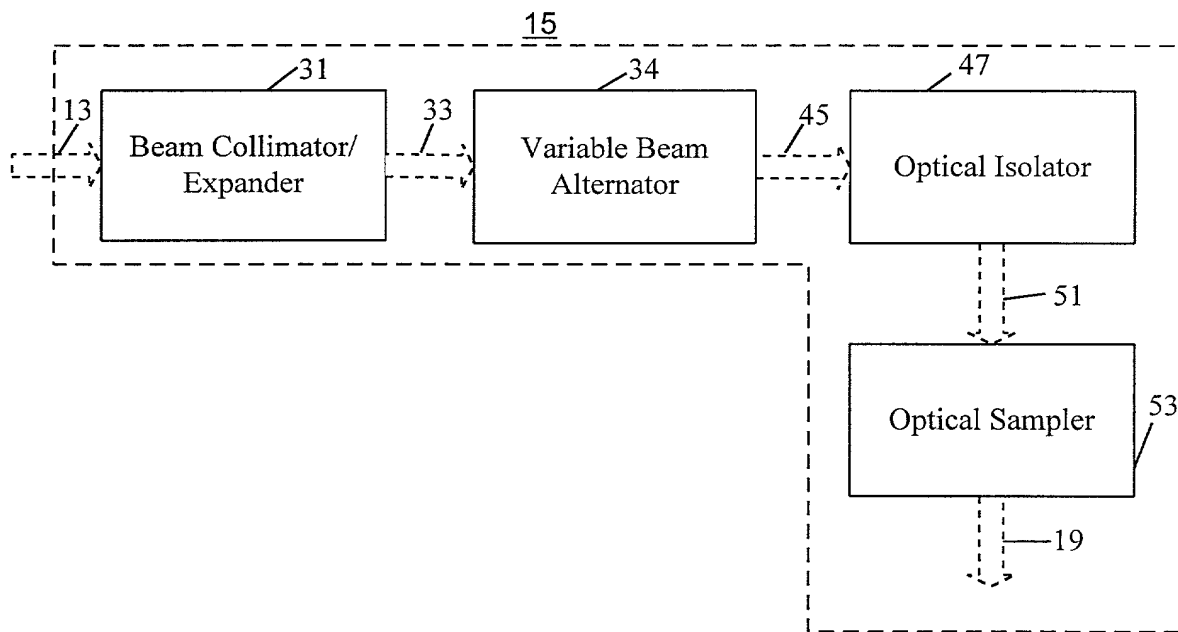


Fig. 2a

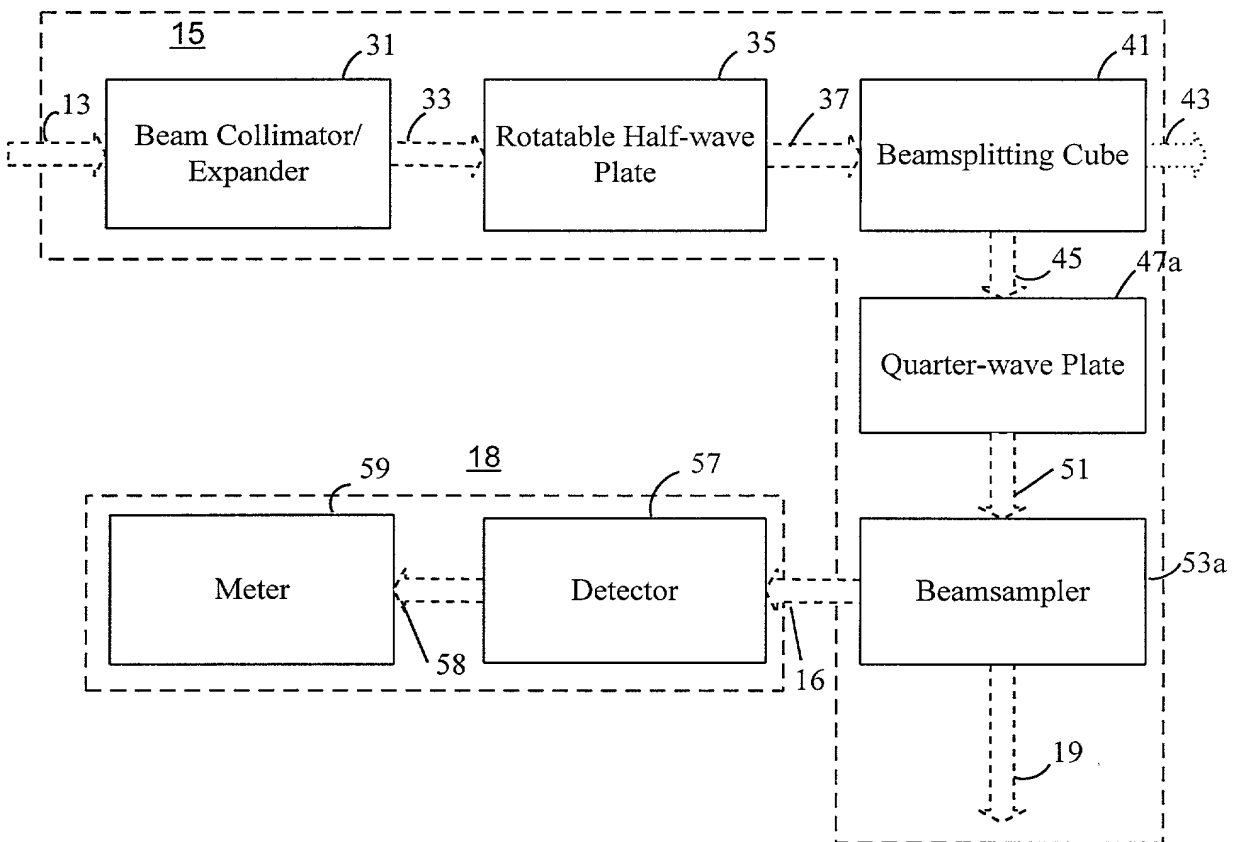


Fig. 2b

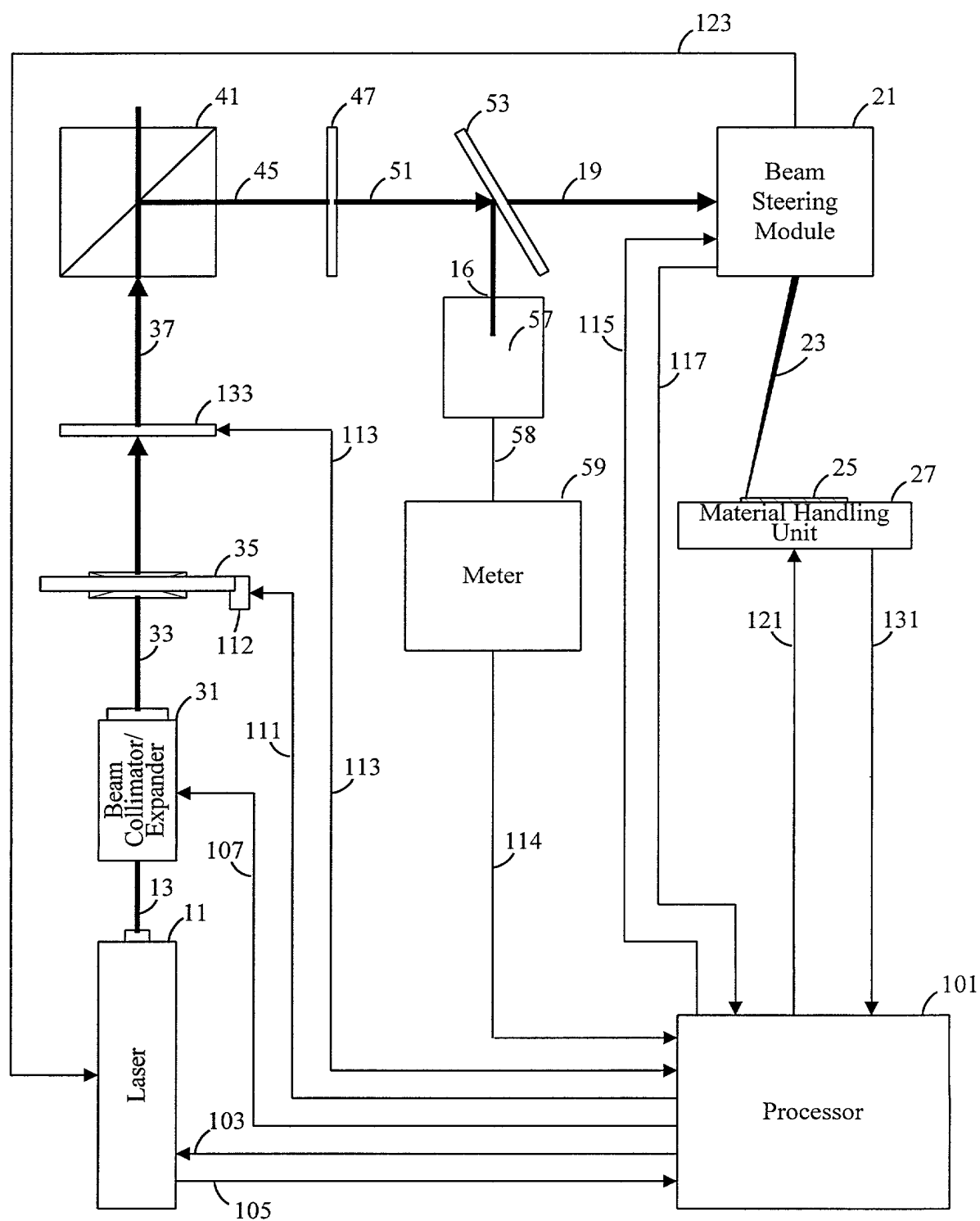


Fig. 3

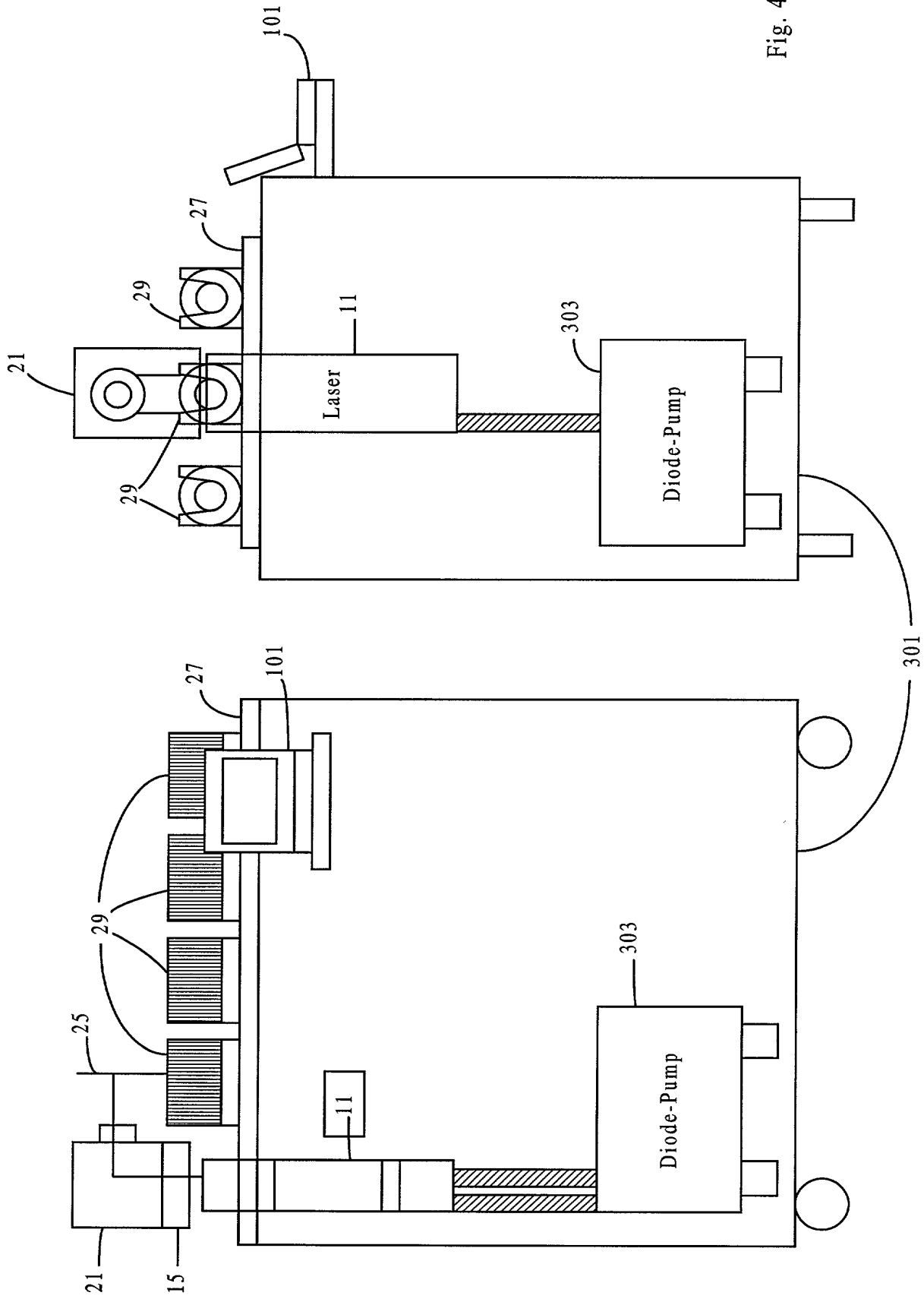


Fig. 4

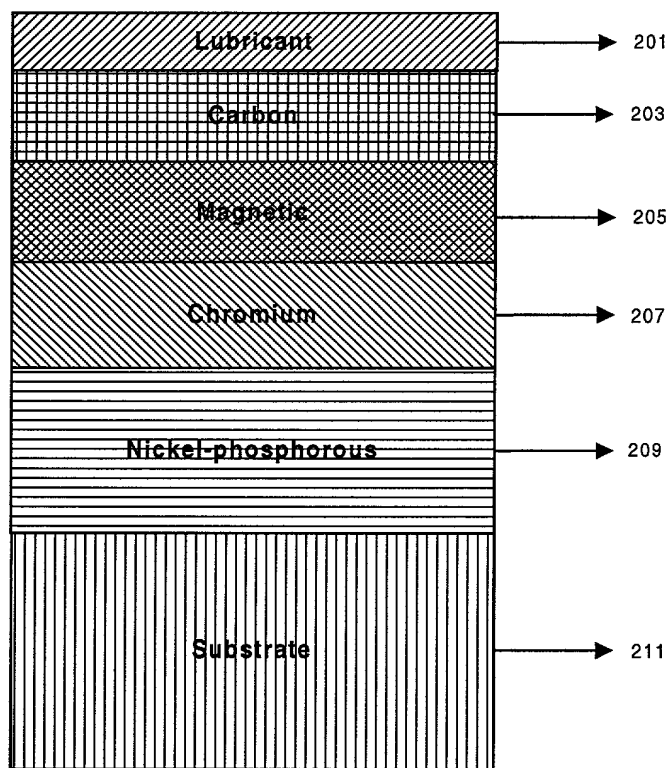


Fig. 5

A black and white micrograph showing a dense, granular polymer matrix. Several dark, cross-shaped or star-shaped features are scattered throughout the field of view, representing crystalline regions or defects. A scale bar at the bottom right indicates a length of 50 μm .

APC 22 -

Fig. 7

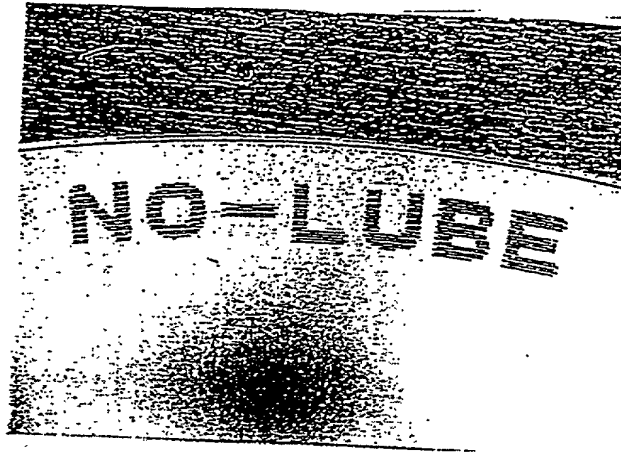
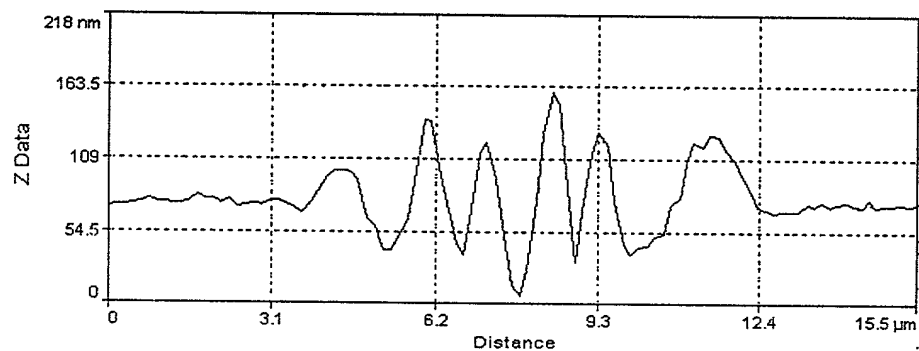
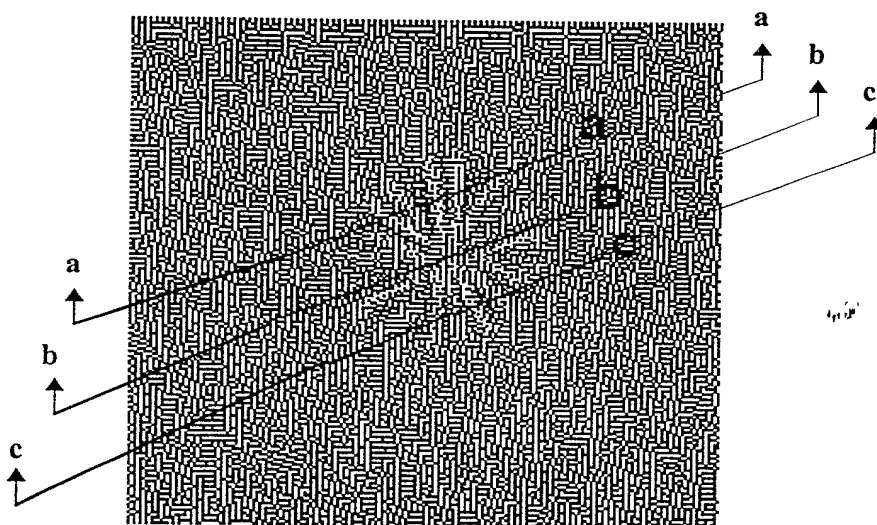
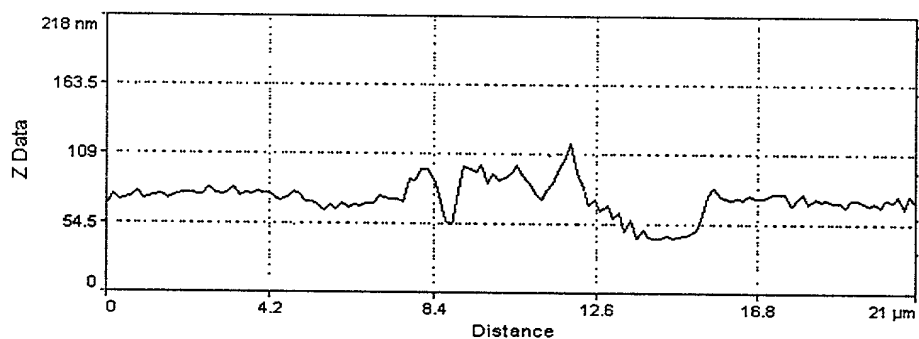


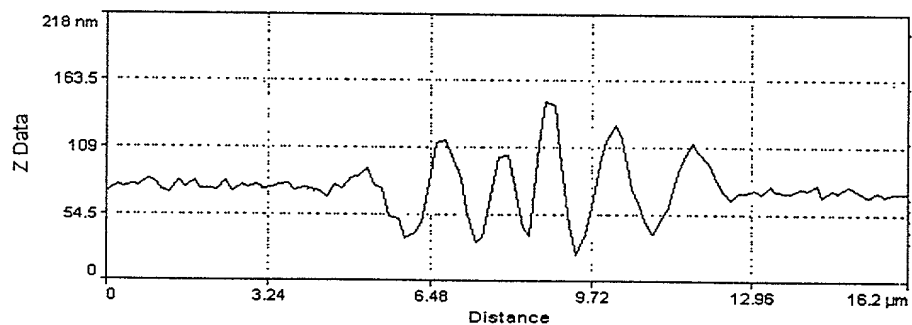
Fig. 8



a



b



c

Fig. 9

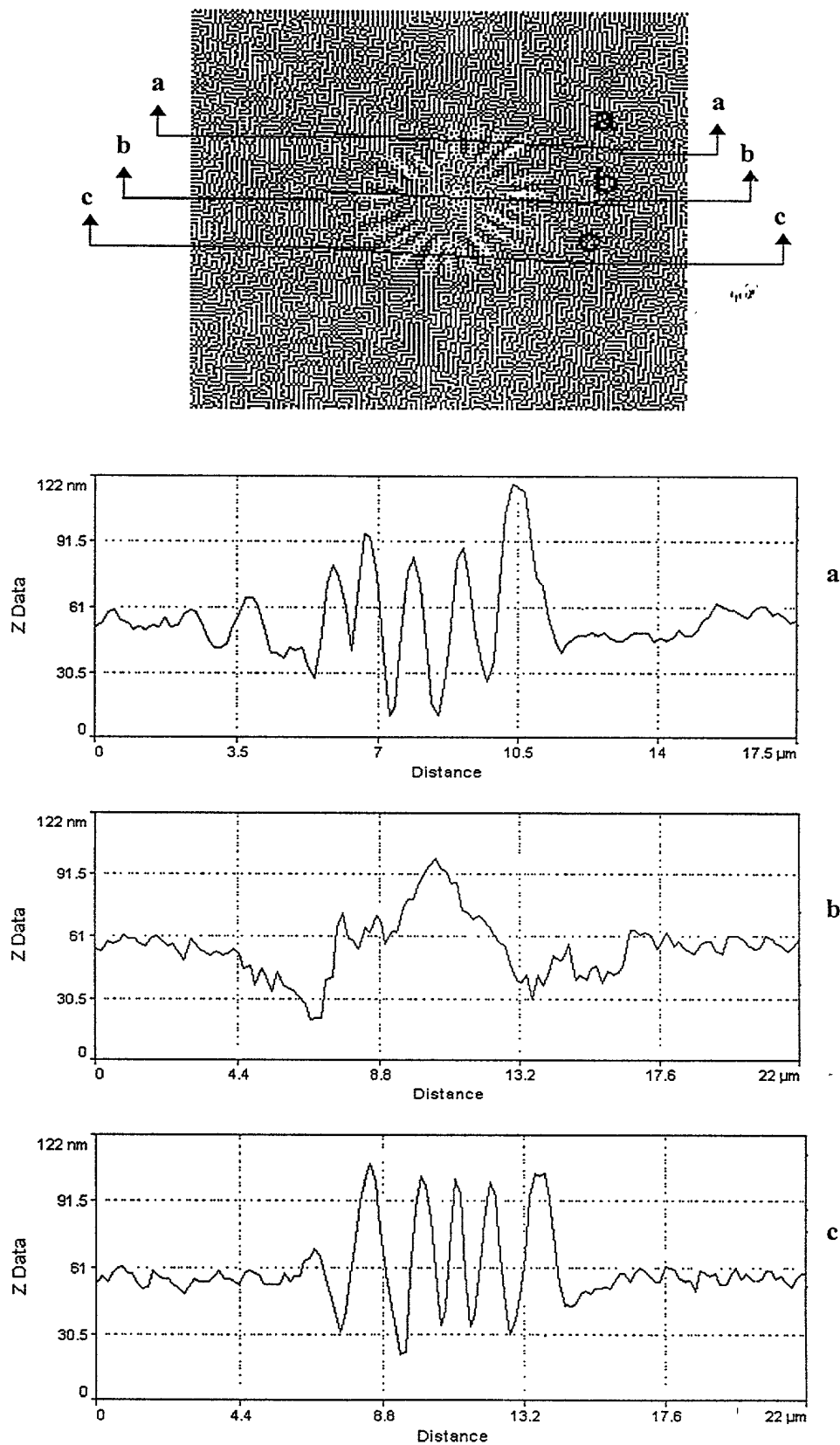
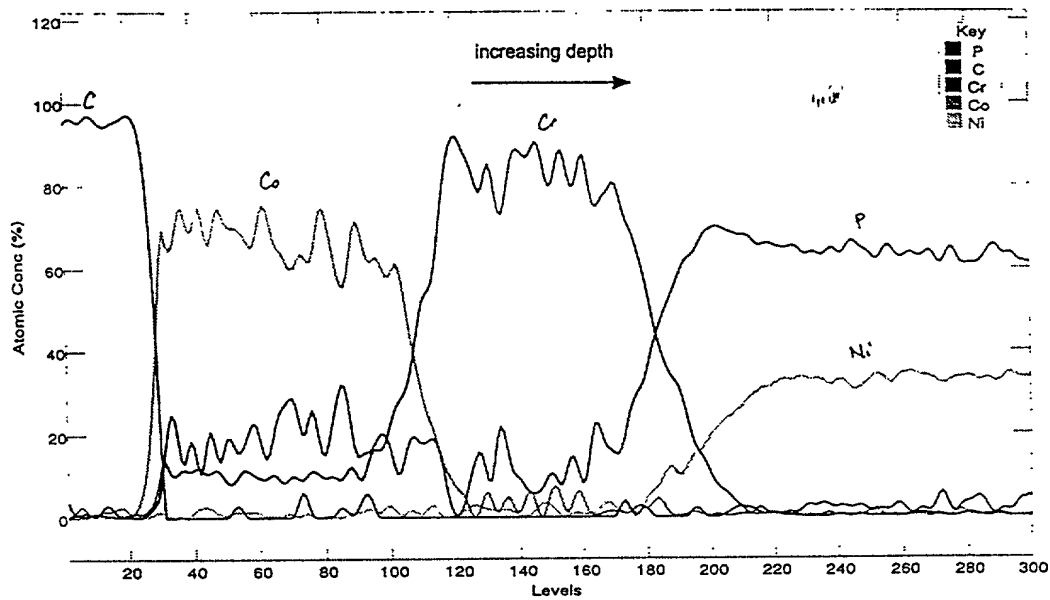
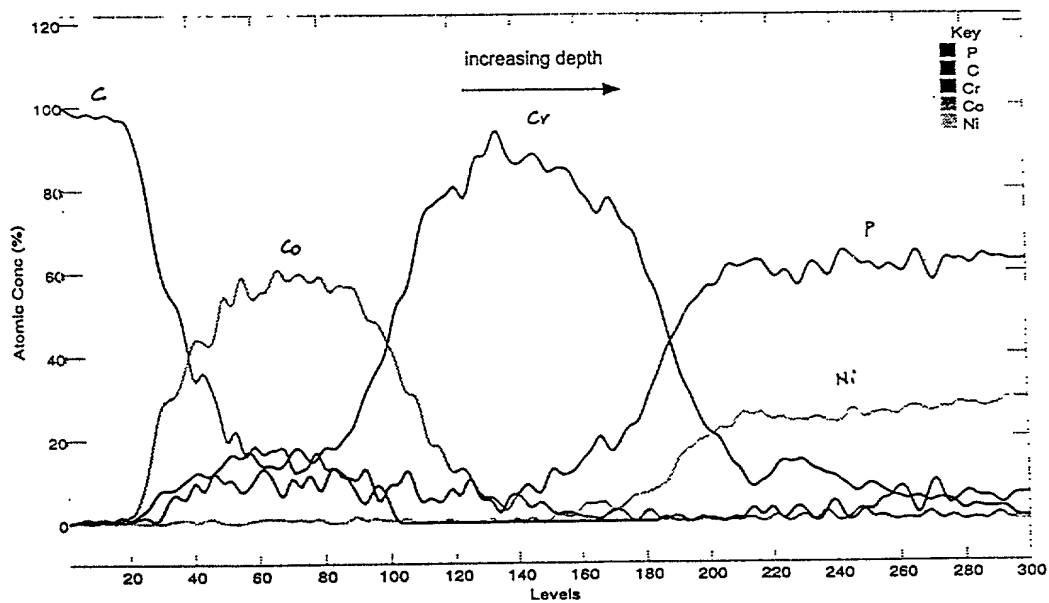


Fig. 10



(b)



(a)

Fig. 11

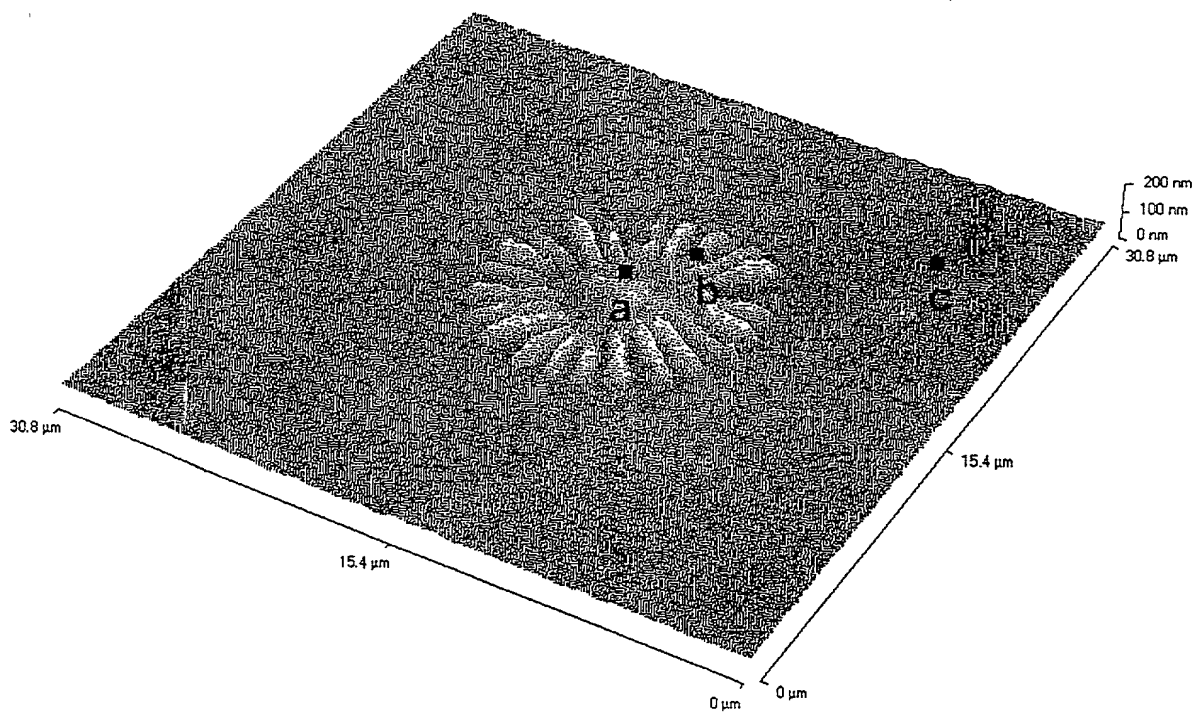


Fig. 12

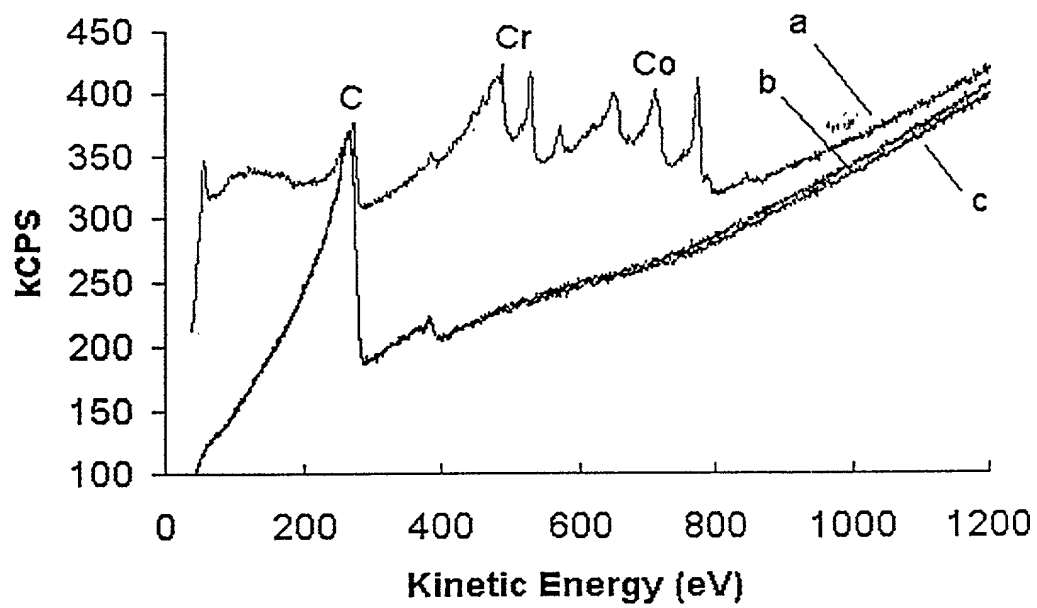


Fig. 13

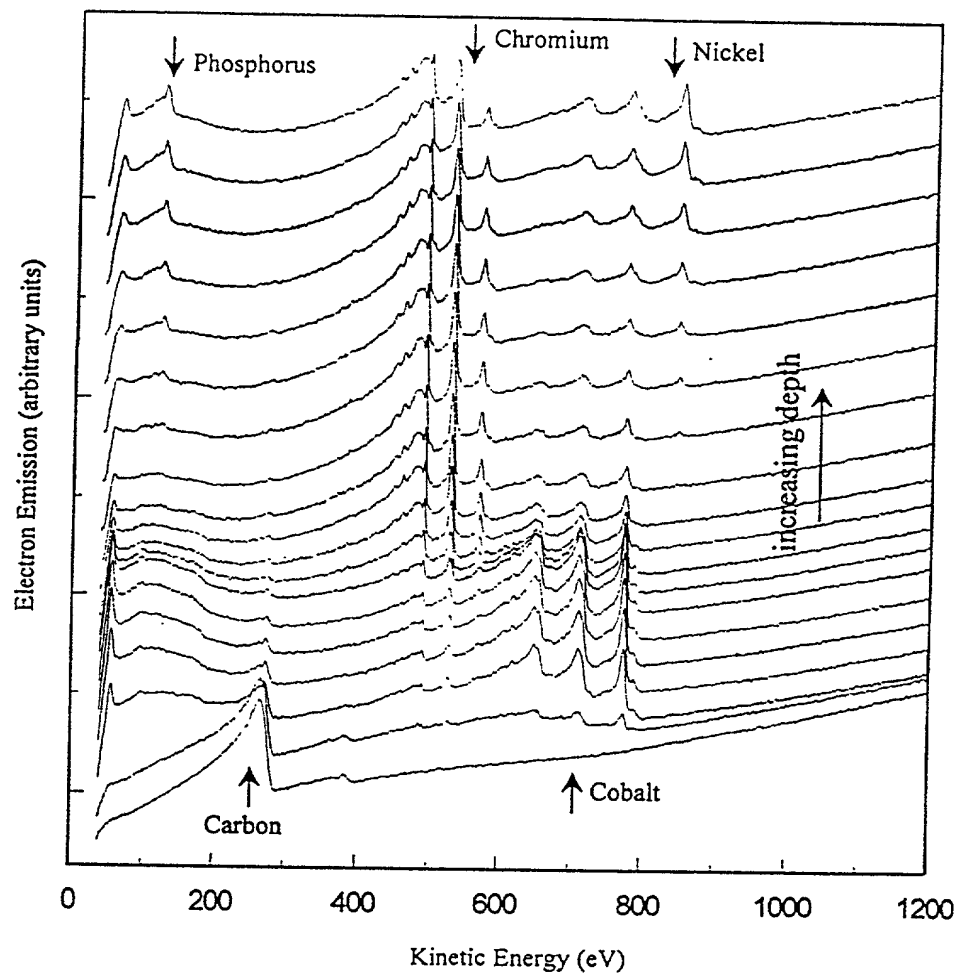


Fig. 14

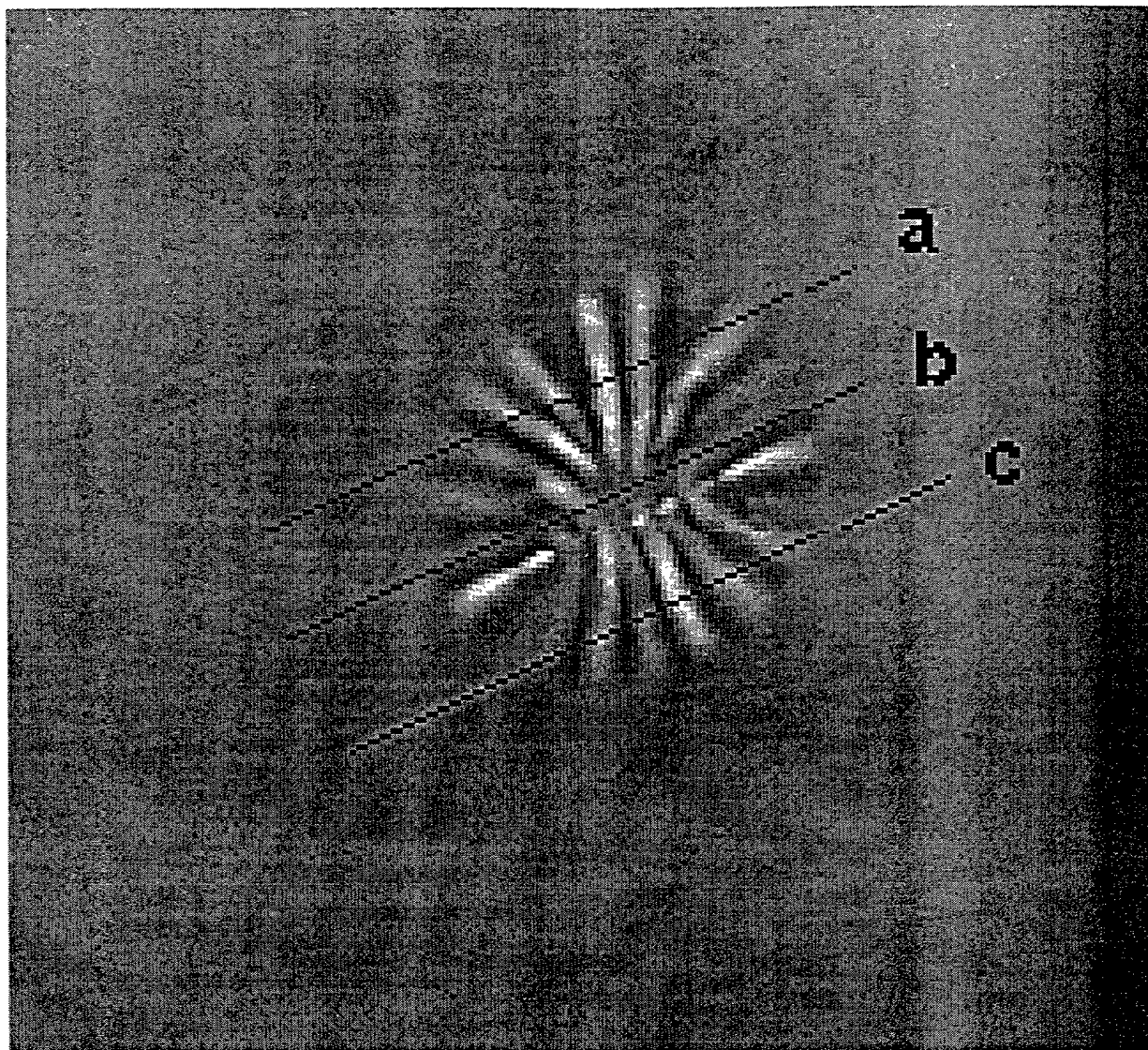


Fig. 15

DECLARATION, POWER OF ATTORNEY AND PETITION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **"METHOD AND APPARATUS FOR PROVIDING ABLATION-FREE LASER MARKING ON HARD DISK MEDIA"** the specification of which

(check one) ☒ is attached hereto
☐ was filed on _____ as Application Serial No. _____
 and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application of which priority is claimed.

Prior Foreign/U.S. Provisional Application(s)

			Priority Claimed	
60/089,465	United States	16 June 1998	<u>X</u>	___
(Number)	(Country)	(Day, month, year filed)	Yes	No
60/089,411	United States	16 June 1998	<u>X</u>	___
(Number)	(Country)	(Day, month, year filed)	Yes	No
60/089,429	United States	16 June 1998	<u>X</u>	___
(Number)	(Country)	(Day, month, year filed)	Yes	No

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.)	Filing Date	(Status: Patented, pending, abandoned)
(Application Serial No.)	Filing Date	(Status: Patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

And I hereby appoint W. POMS, Reg. 18,782; G.P. SMITH, Reg. 20,142; G.E. LANDE, Reg. 22,222; A.C. ROSE, Reg. 17,047; L.J. BOVASSO, Reg. 24,075; D.J. OLDENKAMP, Reg. 29,421; C. DARROW, Reg. 30,166; M.E. HARRIS, Reg. 26,690; K.A. MACLEAN, Reg. 31,118; C. ROSENBERG, Reg. 31,464; M.E. BROWN, Reg. 28,590; E.F. O'CONNOR, Reg. 25,903; R.F. CARR, Reg. 17,110; A. ROTHENBERG, Reg. 17,843; R.L. GAUSEWITZ, Reg. 16,960; M.A. KONDZELLA, Reg. 18,013; A.P. BLOCK, Reg. 35,450; S.R. HANSEN, Reg. 38,486; D.N. LARSON, Reg. 29,401; J.W. INSKEEP, Reg. 33,910; G.F. COTTERELL, Reg. 37,802; H.D. JASTRAM, Reg. 19,777; J.M. KALIS, Reg. 37,650; C.J. LERVICK, Reg. 35,244; C.A.S. HAMRICK, Reg. 22,586; R.O. GUILLOT, Reg. 28,852; J.D. VOELZKE, Reg. 37,957; G.L.

FOUNTAIN, Reg. 36,374; J. BOYCE, Reg. 40,920; C. CHOU, Reg. 41,672; M. IMAM, Reg. 38, 190; OPPENHEIMER WOLFF & DONNELLY LLP, 101 Park Center Plaza, Suite 300, San Jose, California 95113, (408) 795-3000, as my attorneys with full power of substitution and revocation, to prosecute said application and to transact in connection therewith all business in the Patent and Trademark Office and before competent International Authorities.

Address all telephone calls to Chien-Wei (Chris) Chou at (408) 795-3000 and address all correspondence to:

Chien-Wei (Chris) Chou, Esq.
OPPENHEIMER WOLFF & DONNELLY LLP
 101 Park Center Plaza, Suite 300
 San Jose, California 95113


Wherefore I pray that Letters Patent be granted to me for the invention or discovery described and claimed in the foregoing specification and claims, and I hereby subscribe my name to the foregoing specification and claims, declaration, power of attorney, and this petition.

Full Name of Sole or First Inventor: Teng Soon Wee

Home Address: Blk 14 Toh Yi Drive, #06-29, Singapore 590014

Post Office Address: Same as above

Citizenship: Singapore

Inventor's Signature:  Date: 11/6/99

Full Name of Second Inventor: Lian Boon Koh

Home Address: Blk 626 Pasir Ris Drive 3, #04-306, Singapore 510626

Post Office Address: Same as above

Citizenship: Singapore

Inventor's Signature:  Date: 11/05/99

Full Name of Third Inventor: Daming Liu

Home Address: Blk 520 Jurong West St. 52, #07-177, Singapore 640520

Post Office Address: Same as above

Citizenship: People's Republic Of China

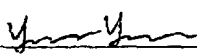
Inventor's Signature:  Date: 10/05/99

Full Name of Fourth Inventor: Yuan Yuan

Home Address: Blk 170 Boon Lay Drive, #10-681, Singapore 640170

Post Office Address: Same as above

Citizenship: Singapore

Inventor's Signature:  Date: 10/06/99

Full Name of Fifth Inventor: Yong Feng Lu

Home Address: Blk 287D Jurong East St. 21, #08-310, Singapore 604287

Post Office Address: Same as above

Citizenship: Singapore

Inventor's Signature: _____ Date: _____

Full Name of Sixth Inventor: Jui Kiat Goh

Home Address: Blk 810 Jurong West St. 81, #02-90, Singapore 640810

Post Office Address: Same as above

Citizenship: Malaysia

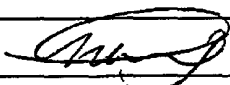
Inventor's Signature: _____ Date: _____

Full Name of Seventh Inventor: Kuan Teck Chang

Home Address: Blk 354 Bukit Batok St. 31, #02-331, Singapore 650354

Post Office Address: Same as above

Citizenship: Malaysia

Inventor's Signature:  Date: 10 June 1999

Full Name of Fourth Inventor: Yuan Yuan

Home Address: Blk 170 Boon Lay Drive, #10-681, Singapore 640170

Post Office Address: Same as above

Citizenship: Singapore

Inventor's Signature: _____ Date: _____

Full Name of Fifth Inventor: Yong Feng Lu

Home Address: Blk 287D Jurong East St. 21, #08-310, Singapore 604287

Post Office Address: Same as above

Citizenship: Singapore

Inventor's Signature:  Date: June 11, 1999

Full Name of Sixth Inventor: Jui Kiat Goh

Home Address: Blk 810 Jurong West St. 81, #02-90, Singapore 640810

Post Office Address: Same as above

Citizenship: Malaysia

Inventor's Signature:  Date: JUNE 11, 1999

Full Name of Seventh Inventor: Kuan Teck Chang

Home Address: Blk 354 Bukit Batok St. 31, #02-331, Singapore 650354

Post Office Address: Same as above

Citizenship: Malaysia

Inventor's Signature: _____ Date: _____